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A QUANTITATIVE STUDY OF THE SUBTERRANEAN MEMBERS OF SOYBEAN

By HOWARD J. DITTMER [1]

A METHOD to facilitate the study of a plant's adaptability for erosion control was proposed by the writer three years ago.[2] Soil samples 3 inches in diameter and 6 inches deep were taken with a cutting tube, and counts and measurements were made of the included plant parts. These samples were found sufficient for making predictions as to a plant's soil-binding efficiency. The tool used for sampling was an iron pipe with an inside diameter of 3 inches and a tapered cutting edge to facilitate entrance into soil when driven with a heavy maul. Samples were taken of widely grown agricultural plants and counts and measurements were made of their subterranean members. Complete quantitative data of Kentucky bluegrass, oats, and winter rye also have been published.[3]

The soybean (*Soja max* Illini) was selected for this study because it is of great economic importance and is widely used in crop rotation even on fields subject to erosion. Soil samples similar to those previously mentioned were taken from a field under cultivation that had then been planted for its third successive year in soybeans. The yield was between 35 and 40 bushels per acre. The soil was carefully washed from the root members, and quantitative data were obtained through counts and measurements of the roots and root hairs. Table 1 gives the statistical data for the subterranean members of soybeans.

The taproot system of soybean is very poorly adapted for erosion control. Most of the branching is from 1 to 2 inches below the surface, giving the topsoil very little protection. The taproot has an average diameter of 2.5 mm. and this accounts for considerable volume but comparatively little exposed surface area for contact with the soil. The secondary roots, although not very numerous, expose more surface area than any other root division. Tertiary roots (those arising from the secondary members) were the most numerous and had the greatest total length. However, because of their small diameter, their surface area was smaller than that of the roots of the preceding category. Although they divide as far as the quaternary division, the roots of this category are exceedingly small; they average only 4 mm. in length and in all expose only 4.6 square inches of surface area.

Table 1.—Data showing totals for soybean roots and root hairs in a soil sample 3 inches in diameter and 6 inches deep (42 cubic inches)

ROOTS

Subterranean members	Total number of roots	Avage root length	Total length of roots	Average diameter of roots	Total root surface
	Number	*Millimeters*	*Feet*	*Microns*	*Square inches*
Main	4	120	1.5	2,500	5.6
Secondary	211	45	31.1	650	30.0
Tertiary	1,899	8	49.5	306	22.6
Quaternary	1,012	4	13.3	233	4.6
Total	3,126	....	95.4	....	62.8

ROOT HAIRS

Subterranean members	Number of root hairs per millimeter of root length	Total number of root hairs	Average length of root hairs	Total length of root hairs	Average diameter of root hairs	Total root hair surface
	Number	*Number*	*Microns*	*Feet*	*Microns*	*Square inches*
Main	0	0	0	0	0	0
Secondary	606	2,271,819	110	819	17	20.6
Tertiary	210	3,190,320	90	941	14	19.5
Quaternary	170	688,160	90	203	14	3.2
Total	....	6,150,299	....	1,963	....	43.3

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[2] Howard J. Dittmer: A Quantitative Study of the Roots and Root Hairs of a Winter Rye Plant (Secale Cereale). American Journal of Botany, July 1937.

[3] Howard J. Dittmer: A Quantitative Study of the Subterranean Members of Three Field Grasses. American Journal of Botany, November 1938.

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Table 2.—Data showing comparative totals for all roots and root hairs in a soil sample 3 inches in diameter and 6 inches deep (42 cubic inches)

	Total number of roots	Total length of roots	Total root surface	Total number of root hairs	Total length of root hairs	Total root hair surface	Volume occupied by roots and root hairs	
	Number	*Feet*	*Square inches*	*Number*	*Feet*	*Square inches*	*Cubic millimeters*	*Percent*
Soybean	3,126	95.4	62.8	6,149,299	1,963	43.3	6,286.1	0.91
Oats	4,713	150.1	49.0	6,370,751	26,386 (4.9 miles)	534.4 (3.7 sq. ft.)	3,785.8	.55
Winter rye	6,410	209.6	77.9	12,536,381	55,108 (10 miles)	1,190.0 (8.2 sq. ft.)	5,869.0	.85
Kentucky bluegrass	84,544	1,260.0	332.0	51,647,770	169,528 (32 miles)	2,447.9 (16.9 sq. ft.)	18,085.0	2.80

Root hairs were found over the surfaces of all roots except those of the primary division, where secondary thickening had completely removed the epidermis. Hairs were most abundant on roots of the tertiary category, chiefly because of the greater length of the roots in this division. Root hairs of soybeans were different in appearance from those of the grasses previously studied. They were very short (90 to 110 microns) and of comparatively large diameter (14 to 17 microns). Because of their size, root hairs of soybeans are poorly adapted for binding soil. Their total surface area is small and they do not extend far from the roots. On the other hand, root hairs of grasses are long and small in diameter, cover a larger area and expose considerable surface. It is this large surface area exposed by root-hair members that is so important in binding soil.

Table 2 presents in summary the quantitative data of the subterranean members of the roots and root hairs of three grasses in comparison with soybean. Bluegrass has over 50 times the surface area exposed by soybean. Winter rye has nearly 30 times and oat has 12 times the subterranean surface of soybean. Kentucky bluegrass, because of its habit of growth, covers the soil much more efficiently than any of the other plants. Its fibrous root system grows evenly and forms a compact mat. Its prodigious number of roots and root hairs present a large surface area potentially in contact with the soil.

Very significant in soil studies is the volume occupied by subterranean members. The last column of table 2 shows the volume expressed in percent. Soybean has fewer root members and exposes very little surface, but occupies more volume in the soil than either oats or rye and about one-third the volume occupied by bluegrass although the latter has over 50 times the surface area of soybean.

A dicotyledonous plant increases its conductive capacity by increasing its diameter in secondary thickening. Monocotyledonous plants, lacking cambium, increase their conductive capacity by increasing the number of main roots arising directly from the stem. This fibrous-type root system is typical of grasses and binds the surface soil tightly. A taproot system, as found in soybean and many other dicotyledonous plants, penetrates the soil deeply but does not bind the surface soil.

All soil in direct contact with roots and root hairs may be considered bound. Particles of soil closely held between the subterranean members may also be considered free from erosion. Consequently, monocotyledonous plants with their small but numerous roots and root hairs and enormous surface are far more efficient than most dicotyledonous plants.

The role of these four plants in binding soil has been known by soil conservationists for some time. This study shows, however, why Kentucky bluegrass is superior to the other plants and why soybean is a very poor plant to be grown on fields subject to erosion. It shows also that the soil-binding potentialities of a plant may be determined in a very short time by making quantitative studies of its roots and root hairs.

According to a 3-years farm-management study by Purdue University, pasture produced livestock feed very much more cheaply than any harvest crop was produced; these calculations were made after costs of labor, seed, lime, fertilizer, rent and taxes were deducted. In fact, pasture produced about 40 percent of the annual feed at 15 percent of the cost. This indicates that every effort should be made to lengthen the grazing season without overgrazing any particular pasture. Fertilizing permanent pastures and making proper use of winter small grain, crop residues, aftermath, and other supplemental pastures make it possible to obtain a very large part of the feed from pastures.—A. T. Semple.

TO BE PUBLISHED SOON

An article by B. W. Allred, "Crested Wheatgrass in Competition with the Native Grassland Dominants of the Northern Great Plains."

STRAWBERRY CLOVER IN THE NORTHERN GREAT PLAINS

By WAYNE W. AUSTIN[1]

STRAWBERRY clover (*Trifolium fragiferum*) is one of the more recent introductions in the Great Plains, and undoubtedly will play an important role in the reclamation of low wet areas where the water table is near the surface. It does well on wet soils which have a relatively high alkali content; however, it makes its maximum growth and produces higher yields of forage on wet soils having little or no alkali.

This new legume is a perennial, low-growing, creeping, pasture-type plant that spreads by sending out trailing stems which root at every joint. It strongly resembles white Dutch clover when not in bloom, although the flowers and heads bear no resemblance to white Dutch. The flowers are rather large and round, and vary in color from pink to white. The mature seed ball, or head, resembles a miniature balloon made up of many compartments. Each of these compartments contains a seed which breaks from the head when ripe and may be distributed by livestock, wind or water. The seed is smaller than that of red clover, but larger than white clover seed, and may vary in color from a reddish brown to a mottled yellow and brown. The seed heads of strawberry clover usually contain a high percentage of hard seed; for satisfactory stands from raw seed, it should be scarified before planting.

Because of its ability to withstand flooding for short periods, strawberry clover is especially adapted to low, wet areas. Its alkali tolerance makes it a valuable plant for use in pastures that are too salty for the more common grasses and legumes. This plant has the ability to establish itself in wet meadows having thick stands of saltgrass, alkali-grass, and alkali weed. In pastures where there is a heavy concentration of salt, strawberry clover will take over the low, wet areas, leaving the saltgrasses and alkali weed on the drier high spots. It has been known to survive salt concentrations up to 4 percent.

Carl A. Larson,[2] working in Washington and Oregon with strawberry clover, found that, in pastures with high water table and with salt concentrations near the surface, the root systems of the plants were restricted and close to the surface. On the better drained soils having a low salt concentration, strawberry clover plants were found to have a rather extensive root system, penetrating to a depth of 31 inches. He also found that flooding helps remove salt concentrations on the surface, and thus makes growing conditions more favorable for this clover.

A 2-year-old stand of strawberry clover, showing two rows of clover planted 3 feet apart in the Lander, Wyo., Soil Conservation Service nursery. Within the 2 years the ground between the original rows has become completely occupied.

Strawberry clover is not a dry-land plant; it will not grow on high, dry ground. White clover and strawberry clover have very similar water requirements. Strawberry clover is able to withstand longer periods of flooding and is more alkali-resistant than white clover.

Strawberry clover is not a native of this country. Dr. E. A. Hollowell[3] states, "Strawberry clover is a native of the eastern Mediterranean and southern Asia Minor countries; however, it has been widely and inadvertently spread by man. It has been observed on every continent of the world; and wherever it is grown, the value of the pasture herbage has increased." It appears likely that strawberry clover

[1] Assistant chief, regional nursery division, Northern Great Plains Region, Soil Conservation Service, Lincoln, Nebr.

[2] Carl A. Larson: The Adaptability of Strawberry Clover to Saline Soils. Bull. No. 353. State College of Washington, Agricultural Experiment Station, Pullman, Wash.

[3] E. A. Hollowell: Strawberry Clover. U. S. Department of Agriculture Leaflet No. 176. 1939.

found its way into this country by way of Australia, probably mixed with other plant seeds. Escaped plants were found in the eastern part of the United States over 50 years ago. Later, small areas of it were found on irrigation projects in several of the western States.

The Soil Conservation Service has had this clover under observation at the Lander, Wyo., nursery for several years. In 2 years' time, because of its stoloniferous growth habits, rows planted 36 inches apart closed in completely. Although strawberry clover seed is somewhat difficult to harvest, it is capable of producing a high yield of excellent quality seed. A 1-year-old stand of strawberry clover, planted in 36-inch rows for seed production, in the Soil Conservation Service nursery at Mandan, N. Dak., produced almost 200 pounds of clean seed per acre under irrigation. When this stand gets into full production it should yield between 400 and 500 pounds of clean seed per acre.

Strawberry clover is highly palatable and very nutritious. All classes of livestock and poultry relish it and usually graze it so closely that seed production is limited. Larson found that strawberry clover grown on alkali-free land had a higher nitrogen and calcium content, but a lower phosphorous content than plants at the same stage of maturity grown on alkali-impregnated soils. Strawberry clover will stand up surprisingly well even when grazed continuously from early spring to late fall. Too close grazing in the late fall however, may result in a high percentage of winter killing which will affect the carrying capacity the following year.

This new legume does best when planted in a grass mixture. A pure stand of this clover may cause bloat; but there is little danger of bloat when it is used in a mixed grass pasture.

Several fields of strawberry clover are scattered throughout the western part of Nebraska and the eastern part of Wyoming. One sizable pasture containing strawberry clover is located in Morrill County, Nebr., northwest of Northport, on the Bart Moore farm operated by Henry Nagel. The Bridgeport C. C. C. camp technicians became very much interested in this pasture and arrangements were made with the owner and the operator to use C. C. C. boys to collect some of the seed on a share basis; 110 pounds of clean seed were obtained and at the same time the camp agronomists collected some very interesting historical data concerning this field.

Mr. Nagel said that when he moved on to the farm in 1935, this pasture of 46 acres was covered with saltgrass and other wet meadow plants. The field was seepy, and during certain times of the year it became very boggy. On May 15, 1935 he turned 44 head of steers on the pasture; after 90 days of grazing it was necessary to supply supplementary feed, and at the end of 105 days the steers had to be moved because there was no feed left. In 1936, the pasture produced only enough for 44 head of steers for 60 days.

In the spring of 1937, Mr. Nagel secured a pound of scarified strawberry clover seed and planted it during May in small plots scattered over the pasture. Each plot was protected from grazing by means of cattle guards consisting of two posts with slats nailed across them. Several different methods of planting were tried. On one set of plots the sod was removed with a shovel and the ground was spaded and packed; the seed was surface-planted, raked in, and then packed again. On another set of plots, the sod was removed but the ground was not disturbed and the seed was surface-planted, raked in, and packed. The third method consisted of giving the area to be seeded a thorough raking without disturbing the sod, then surface-planting the seed, raking it in, and packing it well. In the fall when the cattle guards were removed, Mr. Nagel found clover plants on all the plots, but in every case very much better stands of clover were found on plots where the sod had not been disturbed but only worked up with a garden rake. When the cattle guards were removed from the plots the cattle were still in the pasture. Numerous seed balls were present, filled with ripe seed, and these were eaten by the cattle.

In the spring of 1938, two more pounds of seed were planted and protected as in the previous year. The old plots were not covered, however, and the cattle were allowed to graze them at will. Then during the late summer of 1938 Mr. Nagel made an important discovery: he noticed that small clumps of clover plants could be found widely scattered over the pasture and, in almost every instance, these clumps of clover plants were on or adjacent to old droppings. The cattle had eaten the ripe seed balls the fall before and as the seed passed through the digestive tract of the animals the hard seed coats were softened and made permeable to water. When this excreted seed came in contact with the moist, well-manured earth an excellent stand of clover seedlings was soon started.

By the fall of 1939 the clover had spread over the entire pasture. It is still somewhat patchy, but this condition will not last long because the clover spreads by means of runners which enlarge each patch until the ground is rather thoroughly covered. By the end

of 1942, this field should be one solid mat of clover and grass.

Mr. Nagel has been keeping accurate figures on the number of livestock this pasture is carrying and the amount of supplementary feed he has used each year along with it. The following table shows the benefit he has derived to date through the addition of strawberry clover to this 46-acre pasture:

Year	Number of animal units	Total number of days pastured	Animal days without supplements	Animal days with supplements	Total number of animal days	Total number of animal months
1935	44	90	3,960	660	4,620	154
1936	44	60	2,640	None	2,640	88
1937*	45	70	3,150	None	3,150	105
1938*	78	120	9,360	**	9,360	312
1939	78	107	8,346	2,574	10,920	364

* Strawberry clover seeded in small plots in May.
** Some feed left.

On May 3, 1939, 66 head of steers, 7 horses, 5 milk cows, and 3 calves were turned on this pasture. On August 17, the steers were given about one-fourth full fattening rations. On September 20, all livestock were removed from the pasture although considerable feed was left. The Soil Conservation Service C. C. C. camp then came in and collected 110 pounds of clean seed—and a considerable amount of seed remained after they had finished.

The steers, after being removed from the pasture, were put on full feed. They were sold on December 4, 1939, after having made a gain of 501 pounds per steer, or an average gain of 2⅓ pounds per day per steer while they were in Mr. Nagel's possession. Although no scales were available on the farm to check the exact weights, it was believed that at least half the gain was made while on pasture. If a 250-pound gain is assumed from the pasture, the profits per acre undoubtedly were greater than for any other field on the farm.

These gains speak well for Mr. Nagel's ability as a livestock feeder. He is very modest about his ability, but he is eloquent in his praise of strawberry clover. He reports that it is not "washy" as so many legume feeds are, and that his livestock has not suffered from bloat although no precautions were taken to avoid it.

It appears that strawberry clover is unsurpassed for wet boggy pastures. It also seems to offer considerable promise for irrigated pasture mixtures. It would be well to watch this plant closely and even try some small patches in a low-lying pasture in order to find out what it will do. Certainly this clover shows promise of filling a long-felt need for a wet pasture legume in the irrigated section of the Great Plains and, by utilizing these wet areas for pasturage, a better system of farming is possible for the entire farm.

Land subject to erosion and planted to cotton, corn, and wheat loses an average of approximately 25 tons of soil per acre each year. If we consider the original topsoil as being worth $200 an acre, or 20 cents a ton, an average of $5 should be charged annually against each acre of cultivated cropland for the soil lost. If the nitrogen, phosphorus, and potassium in the soil loss were charged at 5 cents a pound, then the value or this soil loss would amount to about $35.—A. T. Semple.

Good perennial grass pastures, properly stocked, lose only a small fraction of the amount of soil that is washed from land in cultivated crops. Good pastures lose soil more slowly than new soil is formed; thus, they are truly soil building.

Research studies made by the Bureau of Dairy Industry have shown that while the total amount of milk is reduced by feeding principally roughage and pasture, the unit cost is sufficiently less to make the lower production more profitable to the farmer.

Safety Record Commended

The following is from a letter from the Office of the Director of the Civilian Conservation Corps, dated May 31, 1940:

"Receipt is acknowledged of your letter * * * covering personal injuries sustained by C. C. C. camp enrollees while under the supervision of the Soil Conservation Service during the month of April 1940.

"We wish to congratulate your Service on the new all-time low in frequency rate of lost-time accidents per 10,000 man-days worked. This is an excellent record and your field representatives should be highly commended for their efforts in making this record possible.

"We especially wish to congratulate Regions 6 and 7 for having operated 25 and 17 camps, respectively, without a lost-time accident during the month.

"* * * We want to thank you and your entire personnel for your splendid cooperation in our Safety Program and hope that your future reports will be equally as gratifying."

STRIP CROPPING IN THE LAND OF THE THOROUGHBREDS

By EWING JONES [1]

Five inches of rain in a little over 24 hours did little damage to the soil of a tobacco field planted on the contour.

WHEN the Virginiars and the Carolinians poured through Cumberland Gap into Daniel Boone's "dark and bloody ground," the more fortunate ignored the tumbling hills and forests of the mountain country, and went on to the tall canebrakes and buffalo ranges. That country now is Bourbon County—home of the thoroughbreds. Today, it is almost impossible to buy a farm in the rich bluegrass-limestone section, known as the inner-bluegrass, because the land is handed down from generation to generation.

A curious paradox makes Bourbon County unique agriculturally: Less than 12 percent of the land is cultivated, yet that acreage yields 45 percent of the cash income. One crop represents 40 percent of the cash income, yet only 4 percent of the county's acreage is in that one crop. The one crop is burley tobacco. Kentucky leads the Nation in burley tobacco production, and Bourbon County leads Kentucky. Its claim to the best burley in the State is unchallenged. As Phil R. Watlington, county agricultural agent, expresses it, "Bourbon County is shaped like a diamond, and its tobacco glistens like a diamond on the market." The county produces an average of more than 1,000 pounds of white burley per acre each year.

Good quality burley depends on three chief factors. First of all is good quality soil. The soil in the inner-bluegrass is of limestone origin. Generally speaking it has been protected through the years by almost continuous bluegrass cover that has anchored the soil, given it a high content of humus and organic matter and, through absorption, has maintained a fairly uniform water level. Much depends on the climate, factor number two, and on commonsense management, the third factor. The predominant factor, however, is the soil. Burley tobacco is a rich-land crop.

The Soil Conservation Service began work in the inner-bluegrass in 1935, through the operations of a C. C. C. camp at Carlisle, when there was no strip farming whatever in the entire area. Today, 5 years later, contour strip cropping has become the most popular single soil-saving practice in the balanced agricultural planning. Of course, there is much more to the program than strip cropping, but the contour bands of bluegrass and burley stand out above the other individual practices, chiefly because of the excellent sod.

The good sod is most important. Two years ago the county experienced a 5-inch rain in a little over 24 hours, and the creeks roared with flash floods. On the farm of Reynolds Letton, one tobacco patch that had been planted in the usual manner, following the boundary fence, suffered severe sheet erosion and was even scoured to bedrock in spots. An adjoining field owned by Letton but farmed by another tenant, *on the contour*, lost little of the soil so precious to these sons of the pioneers. Just across the creek in a field of corn planted in rotation contour strips, the soil movement was slight. In some instances the soil washed out of the cultivated strips and nearly halfway across the sod strips—but no farther. The good sod checked the flow of water, made it drop its cargo of topsoil, filtered it out, spread out the flow of the raindrops.

Near Millersburg the camp technicians signed an agreement with J. W. Parker in the fall of 1937 and immediately laid out contour strips on all the sloping land to be cropped the next year. When the cloudburst came slight soil movement was noted; but none of the colluvial fans extended across the bluegrass control strips. It was a different story on the adjoining farm belonging to Mr. Parker's sister. A field of similar soil and slope was planted to tobacco in straight rows. After the rain it was found that the eroded soil had covered a fence and piled up nearly a foot

(*Continued on p. 51*)

[1] Regional division of information, Ohio Valley Region, Soil Conservation Service, Dayton, Ohio.

RECLAMATION AND PROTECTION OF DANISH HEATH AREAS

By MELVILLE H. COHEE

THE Danish Heath Society was founded in 1866. The chief objective was to promote reclamation, improvement, and profitable cultivation of waste lands in Jutland of Denmark. At that time about one-fifth of Denmark was uncultivated, and of this expanse the Jutland Heath accounted for approximately 2,800 square miles, including the Danish part of Schleswig.

In ancient times and far into the Middle Ages many parts of the Jutland Heath were under cultivation. During the immediate centuries after the Waldemars (twelfth and thirteenth centuries) there were wars and epidemics which scattered the population. As a result of the wars large wooded areas were burned, and the land was laid bare to the strong western and northwestern winds which came from the sea. As the communities were hampered in their existence and the old balance of land use became more and more altered these areas in Jutland, left unattended, were gradually possessed by the undesirable heather, and thus it was that, in time, the heath became almost entirely uninhabited.

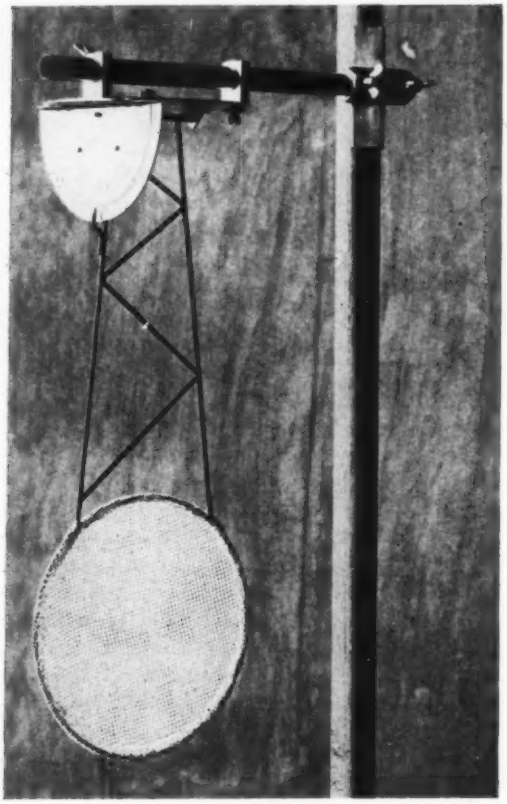
As early as 1723 a Royal Decree by Frederik IV, and later similar measures in 1751 by Frederik V, sought to encourage reclamation of the heath lands by exempting operators from military service and from taxes. But these measures proved inadequate, probably because the pressure for reclamation was not sufficient to start actual work. Another attempt in 1760 was almost a complete failure; German colonists were brought in to do the heavy tasks, but as insufficient preparations had been made for facilitating their work their success in mastering the heath areas was meager. Lack of roads and inaccessibility to marl were the two main handicaps to reclamation prior to 1866.

Col. E. M. Dalgas, founder of the Danish Heath Society, realized that a well-coordinated program must be formulated and carried forward if the heath was to be reclaimed. "Single track" measures had been proved worthless by those who carefully analyzed the conditions. Colonel Dalgas knew that certain fundamentals must be attended to simultaneously; roads must be provided, drainage and irrigation works must be constructed, marl must be made available, and along with reclamation of the land for cultivation and meadows large plantations and shelter hedges must be established to protect the soil from the severe climate. With such a sound program this leader soon commanded the confidence of all who were genuinely interested in the national welfare of the country, and support was given him from all sides.

The work of the Heath Society has moved forward steadfastly from its time of origin. Both private and State subsidy has been given for its work and today the once large waste area is reduced by more than 50 percent. The reclamation and improvement of such an appreciable part of this small country is remarkable—the total area of Denmark is 16,569 square miles. Such success has been possible only through the carefully made plans of the far-sighted leaders, backed by the united will of the people of this old country to find room for expansion and agricultural self-sufficiency in their own land. In addition to reclamation of the heath lands proper, much has been accomplished in the drainage and cultivation of moors and the reclamation of lakes scattered over the country.

The Danish Heath Society is a private organization and, like other societies of Denmark, does not find its origin or rules for operation in a State law. The membership is composed of all who contribute yearly not less than 5 kroner (approximately $1) to the society, or not less than 100 kroner for a life membership. The affairs of the society are attended to by a Board of Directors, consisting of 44 members elected by the total of 9,000 members (at present), and a Managing Committee consisting of 9 members. Officials of the Managing Committee are: The chairman of the Board of Directors; 3 members chosen by the Board of Directors from their 44 members; 3 members from the staff of the State Department of Agriculture; 1 member from the Federation of Danish Agricultural Societies, and 1 member from the Federation of Danish Smallholders' Societies. The society in the last few years has maintained an expanded works program and an annual budget of, roughly, 2 million kroner. The proportion of the budget coming from society members is very small. Work of the society carries on regardless of source of funds, and State subsidy (the primary source of funds) has not been given with any

NOTE.—The author is principal soil conservationist, Soil Conservation Service, Washington, D. C. He made studies in Denmark in October and November 1939 while in Central Europe in connection with a fellowship granted by an American scientific foundation.



1. *A swinging disc anemometer.*

2. *A double-row hedge, 11 to 12 feet high, near Viborg (Jutland), Denmark; Picea glanca, Picea canadensis, and Picea alba.*

demands for a change in the organization; State interests are safeguarded by the civil servant representatives on the Managing Committee.

The field of work of the Danish Heath Society is today far reaching. It includes construction of irrigation canals and drainage works, road building, establishment of forest plantations, planting of hedges, research for and opening of marl beds, building of marl railway routes, construction of embankments and dikes, and cooperation in technical instructions concerning the operation of heath lands. Much of the work of the society involves the furnishing of technical personnel for project planning. In many instances specific State laws provide regulations for carrying out the work—letting bids for work to private contractors, or arranging for labor and materials to be furnished by the State to a given degree, etc. And the society becomes the planning agency, and later the administrative agency, until a specific project is completed. Following completion of many of the different types of projects, the society technicians must inspect the work regularly to assure proper maintenance.

It is impractical in this brief space to attempt to cover in detail all the types and extent of work done by the Heath Society. It should be of interest, however, to the American conservation technician and the farmer to have a brief review of one important and new phase of the operations, namely, the wind velocity measurement project in progress near Viborg. During the last 2 years, the society, in cooperation with Prof. Chr. Nøkkentved of the Royal Technical College of Copenhagen, had made field measurements of the effectiveness of different types of hedges[1] in reducing wind velocity. Professor Nøkkentved's years of experience with research in wind pressures and velocities around buildings and ships provide him with an excellent background for such investigations.[2]

Since the early work of Colonel Dalgas, the Heath Society technicians have recognized the necessity of breaking the effects of the strong west and northwest winds that sweep over Jutland and cause severe wind erosion on the unprotected lighter soils. Even though plantations and hedgerows were established during the 70 years of the society's existence, no well-designed examinations were carried out to determine the effectiveness of hedges in this capacity. Consequently it is only through years of trial and error that the farmers have established patterns mostly to their own liking, and these vary considerably from farm to farm. Different species of trees are used; the density and height of hedges vary; the spacing of hedges generally follows no well-planned pattern; and, despite the prevalence of hundreds of miles of hedgerows, there is still severe damage by wind erosion. It is not

[1] The hedges or hedgerows referred to in this article are of the field-border windbreak type planted in rows. Usually one, two, or three rows are used and they are close together.

[2] Wind Pressure on Buildings, Irminger and Nøkkentved, Ingeniørvidenskabelige Skrifter A Nr. 23, København, 1930. Wind Pressure on Buildings, Irminger and Nøkkentved, Ingeniørvidenskabelige Skrifter A Nr. 42, København, 1936.

uncommon in certain areas that a farmer may need to reseed his grain after a "blow-out."

In this study a swinging disc anemometer, shown in photograph No. 1, was used in the field tests.[3] It consists of a 20-centimeter ring, covered with porous material and swinging at the end of an arm, the angle of which is a measure of the wind velocity. Careful laboratory tests were made in a wind channel, and a monometer was used to establish the curve for converting angle of arm in degrees to velocity in meters per second.

At each field test station (location) two swinging disc anemometers are attached to a vertical bar. One anemometer is 1.5 meters (4.92 feet) above the ground, and the second is swung just above ground level. Results from the anemometer just above ground level proved to be of little use, as it was found that slight changes in topography influenced them. One station is established at the end of the hedge if this is possible, or, at a distance the height of the hedge on the windward side. Here is recorded the wind velocity as it

3. A single-row Crataegus oxyacantha hedge, 13 to 14 feet high. It exerts a retarding influence on wind velocity for a distance of as much as 20 times its height.

reaches the hedge without the retarding effect of the hedge. Four other stations are established on the leeward side of the hedge. One is located at a distance from the hedge equal to 3 times the height of the hedge (3h); a second is placed at a distance of 10 times the height of the hedge (10h); a third is located farther away (15h); and a fourth is placed at a distance from the hedge of 20 times the height of the hedge (20h). The measurement of wind velocity, "free" wind, entirely separate from the windward or leeward side of the hedge, is also determined in the vicinity.

For a given test, a series of readings is made, at 3-second intervals, for a single station, and the data are averaged. For any one trial at one hedge, two rounds of the stations are made, and the final measure-

[3] Hedeselskabets Tidsskrift, Ulgivet Af Det Danske Hedeselskab, Nr. 4, 59 Aarag., April 1938.

Table 1.—Effectiveness of hedge shown in photograph No. 2, measured at hedge and different distances on leeward side, in reducing wind velocity for a distance up to 20 times its height

["Free" wind velocity, 3.10 meters per second, or approximately 6 miles per hour]

Position of station	Wind velocity		Changes in wind velocity *	
	1.5 meters above ground	Ground level	1.5 meters above ground	Ground level
	Meters per second	*Meters per second*	*Percent*	*Percent*
h * * before hedge	2.40	1.20	77.5	38.7
3h leeward from hedge	.65	.30	21.0	9.7
10h leeward from hedge	1.70	1.40	55.0	45.2
15h leeward from hedge	2.80	2.00	90.4	64.5
20h leeward from hedge	3.05	2.00	98.4	64.5

* Percent change is calculated by comparing reduced wind velocity on leeward side of hedge with "free" wind velocity nearby

* * h=height of hedge.

ment recorded for each station is an average of the two calculations.

It is found that hedges which are very compact, i. e., less porous, do not reduce wind velocities over large distances. Therefore, such a hedge as is shown in photograph No. 2 is most effective when in a system of enclosed fields where the hedges are only 50 to 60 meters (155 to 170 feet) apart. This is because the effectiveness of such a hedge is soon lost after the wind goes beyond it for a distance of more than 10 times the height of the hedge (table 1). Other dense hedges in Jutland, of *Pinus mugo*, *Pinus montana*, *Crataegus oxyacantha*, *Sorbus intermedia*, *Sorbus scandica*, and *Sorbus succia* have been tested as well as those similar to the one shown in photograph No. 2.[4] In each instance where the hedge is very close or compact, the results are the same regardless of the species. Tests with the same compact hedges and for wind velocities of 5 to 10 meters per second (approximately 10 to 20 miles per hour) showed the same type of results—satisfactory effectiveness only

[4] Ibid, footnote 2. Data from the study of 30 hedges bear out the conclusions cited herein.

4. A hedge of Sorbus intermedia, Sorbus scandica, and Sorbus succica that is too open in the lower story to allow effective wind velocity control. Too, some ill effects are suffered from the undertow wind current on the leeward side. A single-row hedge.

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over an area of approximately 10 times the height of the hedge. It is the opinion of the Danish technicians that the effectiveness of the different types of hedges here discussed is of the same relative importance when wind velocities are greater.[5]

Those hedges which are not so compact may give less total reduction in wind velocity near the hedge on the leeward side, but they are effective over a greater distance. Such a hedge is shown in photograph No. 3. Following a reduction in velocity at station 3h on the leeward side of these hedges, the change in wind velocity is gradual—it accelerates again to the same force it had when it entered the hedge (table 2). Such hedges, if properly established and maintained, need not be located so close together in order to control the wind and reduce its damaging effects.

Table 2.—Effectiveness of hedge shown in photograph No. 3, measured at hedge and different distances on leeward side, in reducing wind velocity for a distance up to 20 times its height

["Free" wind velocity 5.53 meters per second, approximately 12 miles per hour]

Position of station	Wind velocity		Changes in wind velocity *	
	1.5 meters above ground	Ground level	1.5 meters above ground	Ground level
	Meters per second	*Meters per second*	*Percent*	*Percent*
h * before hedge	4.20	2.80	75.9	50.6
3h leeward from hedge	2.10	1.60	38.0	28.9
10h leeward from hedge	2.20	1.20	39.8	21.7
15h leeward from hedge	3.25	2.50	58.8	45.2
20h leeward from hedge	3.55	2.60	64.2	47.0

* Percent change is calculated by comparing reduced wind velocity on leeward side of hedge with "free" wind velocity nearby.
* * h=height of hedge.

In many hedges the lower branches are not protected from livestock and other damaging effects. Such hedgerows frequently develop a dense growth in the upper story but this alone does not add sufficient resistance to reduce the wind velocity to any appreciable extent. In fact, in Denmark it frequently occurs that serious damage is done on the leeward side of such a hedge by the whirlwind effect of the undertow wind current, while the total reduction of wind velocity is not great at any point. See photograph No. 4 and table 3.

From these early wind velocity measurements, and subsequent data from continued study, the Danish Heath Society technicians expect to enhance their knowledge regarding the types of hedges which can best be recommended. They already recognize that uniform density of the vertical section of the hedgerow, both coniferous and deciduous, is essential. They also believe that the width of hedgerow has little influence on the area of land that the hedge will protect—height and density of obstruction structure (trunks, boughs, and leaves) are the important factors. They are now well able to explain the air current routes about hedges that are dense at the top and open below. With this information and a knowledge of species adaptable to the various soils and climatic conditions of Denmark, the technicians can plan their hedgerow program with more economic precision. In the past some hedgerows have been made wider than they should be, often to the extent of more than one or two rows of trees, in the assumption that the wider the hedge the greater the area of wind protection.

Further examinations are being made in Denmark regarding relation of one hedgerow to another in a series perpendicular to the prevailing winds, or in an arrangement to enclose fields. In many places soil collects in the hedgerows, and further examinations will be made to determine the effect of this condition on the benefits of hedges. Further studies will be made regarding the effects of hedges with and without foliage.

Too often the details of hedgerows are overlooked when we are speculating on the advantages of the trees for wind velocity reduction. The Danish work clearly indicates that, even in cases where great differences in the density of hedges are not outstanding to the more than casual observer, the differences in influence in wind velocity reductions are appreciable. Some hedges have little beneficial effects and others are invaluable. Perhaps it is possible that valuable information relating to hedgerows and wind velocity could be added to that already existing in the United States, if field examinations were made by a process similar to that used by the Danish Heath Society. There are, in some of our wind-erosion problem areas, both new and old hedges that could be used for such a study and detailed information would be valuable for future planning of hedges. And, not only might there be a saving in the cost of establishing hedgerows, but wind velocity reductions and subsequent benefits could be closely calculated in advance of maturity of the trees.

Table 3.—Effectiveness of hedge shown in photograph No. 4, measured at hedge and different distances on leeward side, in reducing wind velocity for a distance up to 20 times its height

["Free" wind velocity 3.4 meters per second, approximately 7.4 miles per hour]

Position of station	Wind velocity		Changes in wind velocity *	
	1.5 meters above ground	Ground level	1.5 meters above ground	Ground level
	Meters per second	*Meters per second*	*Percent*	*Percent*
h ** before hedge	3.25	2.35	95.6	69.2
3h leeward from hedge	2.80	1.90	82.4	55.9
10h leeward from hedge	1.90	2.00	55.9	58.8
15h leeward from hedge	3.10	2.20	91.2	64.7
20h leeward from hedge	....	....	....	....

* Percent change is calculated by comparing reduced wind velocity on leeward side of hedge with "free" wind velocity nearby. ** h=height of hedge.

[5] See sources of information cited in footnotes 1 and 2.

Elymus mollis (American dune grass) clones being obtained for transplanting on barren areas such as the one at the extreme left. Each year the growth of grass is completely covered by new sand and the dune may attain eventually a height of 40 to 60 feet.

GRASS AND ASSOCIATED VEGETATION TO RECLAIM OREGON'S COASTAL SAND DUNES

By T. A. STEELE[1]

IN the fall of 1935 the Soil Conservation Service, with the aid of a C. C. C. camp, started the exacting task of revegetating the barren, drifting sands of the Clatsop plains area on the western rim of Oregon just south of where the Columbia River discharges into the Pacific. In the October 1936 issue of SOIL CONSERVATION, E. M. Rowalt described the area with its destructive surging dunes, and the control program initiated by the Service.[2] The program was then but a year old, and the studies of native and introduced grasses for use in halting the eastward advances of the dunes had just begun. In this article, progress of the work during the past 3½ years is described and illustrated, with special reference to plants that have been found valuable for stabilization of dune areas in this coastal region. Control measures were found to involve basically an understanding of ecological principles and their correct application. A definite plant succession, following in proper sequence and involving highly specialized plants adapted to the particular edaphic and climatic environment, is now being used.

Control measure on any coastal sand dune area are fundamentally the same. First, intensive grazing and extensive trespassing by man must be eliminated. Fire also constitutes a hazard where woody species are included within the climax cover. As the prevailing winds are landward and the source of sand is the beach, it is obvious that a fore or front dune will retain a large percentage of the sand near the source, thereby giving vegetation to the leeward a opportunity to recover.

To establish a fore dune two parallel rows of pickets, 4 inches by 4 feet, are driven into the sand 30 feet apart, immediately above the high tide line. The pickets collect and retain wind-driven sand particles. When sand reaches the tops of the pickets it is planted to sand-binding grasses—Holland grass (*Ammophila arenaria*) and sea lyme (*Elymus mollis*). The new dune may eventually build up to a height of 40 to 60 feet as a result of sand deposition and regrowth of the planted grasses. Rapidity of growth is in direct proportion to the annual growth of the grasses as shown in photograph No. 1.

The barren areas behind the fore dune likewise must be planted to sand-binding grasses (photograph No. 2). The grasses *Ammophila arenaria;* beach grass (*A. breviligulata*); and *Elymus mollis* are capable of withstanding sand blasting and sand inundation and are planted during the rainy season (November through March) 18 inches apart in rows which are also 18 inches apart. Rows extend crosswise to the prevailing winds. Within one or two years these grasses prevent any appreciable sand movement within the

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[2] E. M. Rowalt: Anchoring the Clatsop Dunes with Vegetation. SOIL CONSERVATION, Oct. 1936.

Sand encroaching on Sitka spruce reproduction. The shrubby growth is Cytisus scoparius (Scotch broom) and Salix sp.

treated area and make conditions favorable for the succeeding plant association.

The secondary plant community may include yellow sand verbena (*Abronia latifolia*); silky beach pea (*Lathyrus littoralis*); *Lupinus littoralis;* bur sage (*Franseria* sp.); *Carex macrocephela; Poa confinis;* seashore bluegrass (*Poa macrantha*); and dune bent (*Agrostis pallens*). Establishment of these plants through seed is an arduous task, but preliminary seedings under favorable conditions appear promising. Reproduction through vegetative means has a higher percentage of survival than by seeding, though the latter practice is by far the more economical.

Complete establishment of this vegetal group will make conditions favorable for the tertiary plant association. Plants within this group include sod-forming grasses which ensure stable control unless man-made maladjustments interfere. This climax vegetative cover may become established by natural plant migration or seeding, and it includes red fescue (*Festuca rubra*); Canada bluegrass (*Poa compressa*); velvet grass (*Holcus lanatus*); Australian ryegrass (*Lolium italicaum*); *Agrostis* sp.; *Carex* sp.; and moss, as well as numerous other plant genera.

An outstanding example of the beneficial effects afforded by leguminous plants is seen on the semisterile dune sand. Grasses which follow the sand-stilling plants are very slow in becoming established when sown alone. The seedlings are slow growing and yellowish in color, compared with vigorous dark-green and rapid-growing seedlings when sown with a legume. This same compatability continues as the grasses grow older. A straight seeding of *Poa macrantha*, for instance, acts as a "bunch grass," but when growing with a legume it will form a dense, rank growth and a sodlike covering.

The Soil Conservation Service does not expect to transform this wasted, barren sand area within a period of 5 years to its native state with a growth of tall grasses and legumes. But through strict adherence to formulated and established control measures, the Clatsop plains should revert in time to a vegetative cover similar to that found by the Lewis and Clark expedition. To ensure this transformation, capable and alert county commissioners and directors are striving to bring this area under public ownership. Such action would eliminate land exploitation and prevent a possible reversion to destructive migratory dunes.

SCHEDULED FOR EARLY PUBLICATION

An article by Hugh G. Calkins and D. S. Hubbell, "A Range Conservation Demonstration in the Land of the Navajos."

WATER CONSERVATION IN HOPI AGRICULTURE

By GUY R. STEWART and ERNEST A. NICHOLSON [1]

IN recent years agricultural agencies have become greatly interested in methods of conserving water and stabilizing crop and pasture growth in the drier portions of the Great Plains and the agricultural valleys of the West. In view of this, it may be helpful to examine some of the methods used for centuries by primitive cultivators of the Hopi villages of northern Arizona in their efforts to make a living in the less favorable parts of a semidesert region.

Although the Hopi are commonly considered members of the Pueblo group of Indian tribes, it should be noted that seven of the eight villages speak a language related linguistically to the neighboring Shoshonean tribes such as the Utes. Apparently the original Hopi came in contact with the Pueblo Indians at an early period and completely absorbed Pueblo culture with its traditional observances used to propitiate the powers believed to govern the success of crops in this arid land. Whether it is due to the remoteness of their location or to the devotion the Hopi felt for their acquired culture, they have been less affected than the Rio Grande Pueblos by contact either with Spanish explorers or with the influences of modern American life. The eighth village of the Hopi communities, Hano, located on First Mesa, belongs to the Tewa language group of the Rio Grande. These villagers took refuge at the head of the first mesa trail after the Pueblo revolt of 1680 and have continued to live there since that time.

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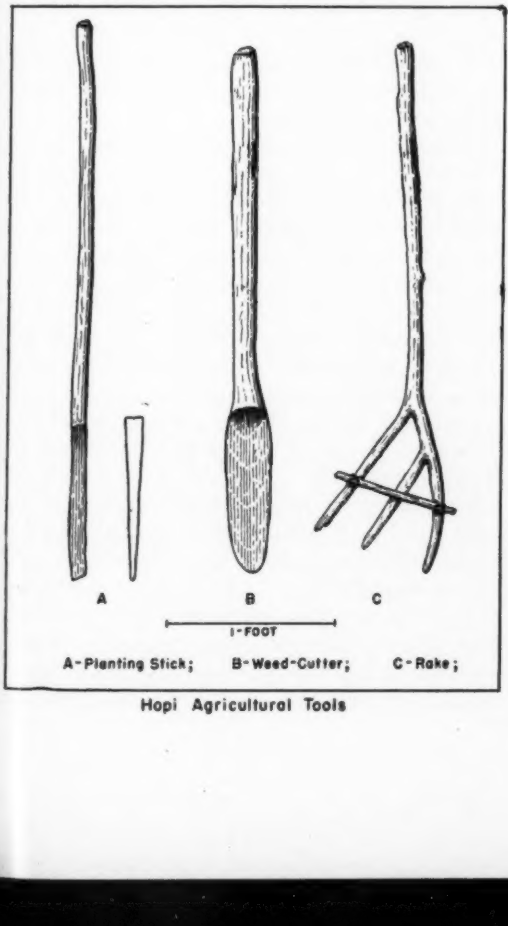


Hopi Agricultural Tools

The three southern branches of Black Mesa, on which the Hopi villages are situated, are usually spoken of as the first, second, and third mesas. No records have been obtained of the precipitation on the higher portions of the northern mesa; but the relatively heavy growth of juniper and piñon indicate that it is materially higher than the 16-year average of 12.7 inches (4) reported at Keams Canyon, some 13 miles from the first mesa villages of Walpi, Sichomovi and Hano. The elevation of the Hopi villages on the first mesa is about 6,000 feet, while the agricultural land on the southeast and southwest is some 300 feet or more lower. In contrast to this the higher land on Black Mesa rises to a height of 7,000 to 8,000 feet, which probably accounts in part for a greater precipitation on the uplands.

This higher rainfall in the upper mesa country provides two important sources of water which have been utilized by the Hopi to supply part of their crops. The major part of the upland run-off finds its way into a series of streams heading in Black Mesa and flowing out on to the plains to the southeast and west of the mesa village lands. In addition, part of the upper rainfall forms a seepage of underground water that moves along the mesa top. The upper strata capping the rocky formations consist of relatively permeable sandstone which dips southward. The sandstone is underlain by compact shales and movement of water into the lower strata is extremely slow. Thus it is that the underground seepage moves along the shale beds until the junction of the two formations is reached some 50 feet above the base of the cliffs where the Hopi villages are situated. This gives rise to a series of springs that form a valuable source of water for the village terrace gardens.

There is no indication that the rainfall on the croplands adjacent to the three mesas is heavier than that recorded at Keams Canyon. Even were this light rainfall well distributed throughout the growing season,

it would be insufficient for field crops such as corn and beans. The records, however, show enormous variation in annual precipitation which ranges from 5 inches in the driest years to 15 inches in the wettest. During most years there is a variable snowfall which has averaged about 27 inches, although it is doubtful that much of this moisture is effectively stored in the soil—this since the period from April through June, following the months when snow falls, is the driest and windiest of the year. Hence, evaporation is high during the period of planting and early crop growth. The most usual rains throughout the Southwest, especially during summer, are torrential thunderstorms of short duration and such as to produce rapid run-off.

These conditions point to the necessity for supplementing local rainfall by utilizing flood flow and underground seepage if crops are to be raised successfully. The methods developed by the Hopi in raising their staple crops of corn, beans, squash, melons, and peaches are based entirely on their own observations of local conditions and antedate any contact with white civilization. Success of the Hopi plantings depends upon the use of flood water run-off, as well as upon utilization of subsoil seepage areas and the development of terrace gardens on land adjacent to springs.

The greater part of the run-off from the higher mesa lands comes out in narrow streams which spread out over alluvial flats where the narrow canyons cutting the southern portion of the mesa give place to the flat valleys south of the Hopi villages. These lower lying valley lands may receive three or four floodings during June, July, and August. Since the flood flow is largely uncontrolled, water may at times stand to a depth of 5 to 6 inches until the excess is removed by evaporation and percolation into the subsoil. This shows one of the risks of flood water agriculture, for the smaller shoots of corn in valley fields may be drowned out by standing water. The fields along the sloping edges of the valley devoted to beans, melons, and squash depend upon run-off originating on the sides of the mesas.

In the lower flood fields an excess of water may wash out the corn where the current is excessively strong or may bury parts of the planted land under a heavy load of sediment. It appears probable, however, that risks such as these always have been a part of the systems of flood water agriculture practiced since early times. This is indicated by studies made by Mr. Nicholson, coauthor of this article, of the evidences of early agriculture found around many prehistoric sites. In addition, Dr. Ruth Underhill, (6), who has studied Indian irrigation among the Pima and other tribes, has concluded that most primitive irrigation tended to be of the flood water type, rather than systematic regular applications.

The observations on Hopi flood-water methods recorded in the following are based especially on the field studies of Mr. Nicholson who has worked in this portion of Arizona for several years. For the convenience of interested readers, references are made to several accounts that treat more generally of primitive agriculture in the Southwest.

The land devoted to beans, squash, and melons is on the more sandy soils along the lower edges of the mesas where local run-off from the mesa sides supplements the variable rainfall. Fields for these crops are found also on the upper mesas, near the peach orchards, where seepage from underground drainage makes cropping possible. Most of these lighter lands have brush checks placed across the fields, against the prevailing winds, to reduce soil drifting and prevent the young seedlings from being cut off at the ground level.

In addition to the two sources of water that have been discussed, the larger springs at the base of the mesas furnish irrigation water for several series of terrace gardens in which sweet corn, chile peppers, onions, and other introduced vegetables are raised with great success.

In general, the corn land lies in the valley flood-water areas where more productive sandy loams and clay loams may be found. In places, however, hills of beans are sometimes planted between widely spaced hills of corn, on the lighter soils.

No tendency toward any system of crop rotation has been noted. This agrees with the observations of Beaglehole (1), who found that each family usually planted the major portion of inherited clan lands to the same crop each year. Forde (2) (3) has mapped the distribution of the various clan fields in the cultivated areas adjacent to First Mesa. The point of special interest in this connection is that each clan possessed land in several separated parts of the village fields. Hence, the chance of complete crop failure for any group of families from an excess of flood water, destructive wind, or a local concentration of cutworms was greatly reduced.

It was observed that prevailing winds from the southwest tended to blow away the lighter surface soil from the western side of many of the fields on the lighter soils. This caused a gradual shift of land use, as the cultivator often moved the border of his area some yards to the east each year. Finally a time would come, after a field had been cultivated for a period of years, when most of the lighter fractions of surface

Hopi terrace gardens supplied with water from Wipo Spring, First Mesa.

soil would be removed. Such a field then would be allowed to grow up to weeds and small brush. After a few years, sufficient silt and fine sand might be intercepted by this cover to permit that moisture be retained in the subsoil and the land be returned to cultivation. This process has gone on for many years. The line of soil blown away tends to form a definite dike extending out from the field border. The authors have noted this sign of early cultivation in a number of places in the Hopi and Zuni country where other evidences of human use have disappeared.

The preparation of the fields for planting is extremely simple. This work starts in late February and is completed at intervals during the spring period. Because of the danger from wind erosion when the soil is excessively pulverized, the plow has never been favored by the Hopi cultivator. Many men still cling to the use of the primitive wooden tools described by Hough (*5*) and shown in the accompanying sketch. Weeds and brush are removed either by the digging stick (A) or the wooden pusher hoe (B). Latterly some of the Hopi have adopted a heavy steel hoe for digging out weeds and cultivating the soil. Each family ordinarily prepares its own land by chopping off the weeds with the hoe and removing small brush by prying it out of the ground with the digging stick. Brush fences and windbreaks are rebuilt on the lighter soils where crops other than corn are to be raised. Any available type of brush, or tree branches, may be used for this purpose. The same windbreak material will be allowed to stay in the ground even after it is defoliated, so long as the branches give some protection against wind action; but from time to time the low hedges will be reinforced when necessity arises. In the melon and bean fields the old roots will be removed as part of the land preparation, but in corn land the corn stumps of the previous year will be allowed to remain in the ground as a guide in order that the corn will not be placed in the same spot, and thus there is an alternation of planted area within the same fields.

Planting may start in late April or early May, depending on the season. On the first mesa, Beaglehole (*1*) reported that a series of nine ceremonial planting dates were fixed for the different crops. No such sequence has been noted on the second mesa. Here the villagers reported that each man observed the sun for himself and determined when the season was sufficiently advanced for the early crops. Watermelons are usually put in the ground first and followed by beans and early ceremonial sweet corn. The planting of the main corn crop does not start until the town crier announces that corn will be planted for the town chief 4 days later. The planting procedure is an interesting combination of mystical observance and sound agricultural practice based on long experience.

When the working party is assembled to plant for the town chief the men gather together for a ceremonial smoke and to breathe prayers for rain. Prayer sticks are placed before a field shrine and a handful of corn meal is sprinkled in the six major directions. After

the proper observances, the planters line up along the side of the field, so that each will plant some three to five paces apart. The rows are spaced in between the rows planted the previous year and the hills are staggered in each adjoining row so that no hill is opposite another nor are hills planted in the same spots as in the previous year.

Each planter clears away the surface soil with his foot and then digs a trough-like hole from 12 to 16 inches deep. The damp subsoil in the bottom of the hole is loosened and from 10 to 20 seeds are planted and covered to a depth of 8 to 10 inches. This deep planting enables the plant to obtain the maximum benefit from the stored soil moisture and develop a root system that will resist wind or excessive floodwater. The planting of a large number of seeds permits development of a leafy clump of stalks which protects the center stalks from damage by high winds. The excess seed also provides sufficient plants so that a stand is likely to be obtained even though mice or cutworms may invade the field. As soon as the corn sprouts, the soil about the hill is kept loose with a digging stick and weeds are removed with a weeding hoe. If the hill is in an exposed position it may be protected by a small brush fence or by circles of protecting stones. In many instances the hills are surrounded by low banks of earth to retain rain or floodwater.

The planted crops receive considerable attention during the early period of growth. Mice and rodents are trapped and cutworms are picked off by hand. Portions of the fields which fail to receive floodwater are leveled off or roughly trenched to promote a more even flow. Additional small windbreaks are constructed to protect squash, melons, or beans which are found to be exposed to the prevailing winds. Weeds are cut with a hoe so as to conserve moisture during the time of most rapid development of the crop.

In the early period of Spanish settlement the Hopi acquired peach trees either from the missions or by trading with the Rio Grande Pueblos. Since that time the cultivation of this fruit has had an important place in the Hopi agricultural practice. Observation on the part of the Hopi orchardists showed that the seepage from springs and from underground water gave a supply of subsoil moisture adjacent to the mesas which was adequate for tree growth. Although there are a few budded trees on the mesas most of the new plantings are native peach seedlings. The fruit from these seedling trees is practically all freestone and though small, is excellent for drying. The peach trees are raised from seed, or cuttings, which replace the older trees as they pass their productive period. The young trees require careful attention and often need to be watered by hand until they are well established. The trees are planted by individuals in common village lands or clan fields and belong to the person who sets out and tends the tree.

Summary

Hopi agriculture constitutes an interesting combination of traditional ceremonial observance and sound conservation measures well adapted to semidesert conditions. Floodwater irrigation is the basis of crop production. The source of this floodwater is partly the run-off from the higher land of Black Mesa and partly local run-off which supplies small fields at the base of each mesa. Permanent springs supply water for a series of terrace gardens which produce chile peppers, onions, early corn and green vegetables.

(*Continued on p. 51*)

Brush checks, Second Mesa, recently put in to stabilize sandy land.

SOIL-CONSERVING PRACTICES SAVE FARM LABOR, POWER, AND EQUIPMENT USE

By RICHARD H. FLYNN [1]

WITH increased emphasis on the conservation of our agricultural resources, not only have new farm practices been established, but methods of carrying out the old practices have been changed. Contour farming has been recommended for the conservation of both soil and moisture. As this is a new practice in many parts of the Middle West, its permanency will depend on its efficiency in production, its immediate effects as an aid in the control of erosion, and how well it fits into the farm business.

In an attempt to measure the efficiency of contour farming as compared with the conventional or up-and-down-hill method, data were collected on a field basis in one Nebraska area [2] for 1939. Records were taken on 139 fields of corn, barley, and oats on cooperating and noncooperating farms. Of these fields 79 were farmed on the contour, and 60 by the up-and-down-hill method.

Data were collected by survey for the operations performed up to the date of visit to the farms. Then forms were left with the operators so that they might keep records of the time and fuel used for the remainder of the operations in producing and harvesting the crop. The information collected on the fields includes the number of hours of man labor, horse work, and tractor time, the number of gallons of fuel consumed, and the acres covered for the various operations of disking, listing, harrowing, cultivating, drilling, and broadcasting. Data were also collected relative to the variety of seed, date of seeding, rate of seeding, and previous treatment and cropping history of the field. A record of each operator's machinery was obtained; this included such information as make, model, and size of tractor, and type and size of all other equipment used on the fields selected for study.

On the whole, the equipment used by the farmers who were cooperating in the soil conservation program in this district was similar to that of the operators who farmed by straight-row method. Within each group, however, there was some variation in the power rating of the tractors and in the capacity of some of the other equipment. In order to set up comparable conditions, as far as the machinery was concerned, for comparing the results obtained on contour- and noncontour-farmed fields, the tractors were grouped according to the drawbar horsepower rating.[3] Other pieces of equipment were grouped on the basis of working width, and teams were grouped according to the number of horses worked as a unit. The data from all of the fields studied in this district were tabulated according to the above-mentioned groupings.

Contour listing of corn was one of the more popular practices adopted by the cooperators in the soil-conservation program in the Plum-Beaver district. The usual tillage practices followed in the production of listed corn were disking, listing, harrowing, go-deviling, and two cultivations. Although a large proportion of the fields were farmed almost exclusively with tractors and tractors equipment, some fields were farmed either entirely with horse equipment or with a combination of tractor and horse equipment. The tables shown with this article indicate the average number of minutes of man labor and horse work, and gallons of fuel used per acre for performing each of the several operations in producing listed corn and in the seeding of small grain, such as oats and barley.

Table 1 shows the average time and fuel used in producing an acre of listed corn on fields farmed by the contour and by the straight-row or up-and-down-hill methods.

Table 1.—Average time and fuel used per acre on 24 contour- and 11 noncontour-listed corn fields

Operation	Time used per acre		Fuel used per acre	
	Contoured fields	Noncontoured fields	Contoured fields	Noncontoured fields
	Minutes	*Minutes*	*Gallons*	*Gallons*
Disking	20.3	19.8	0.47	0.52
Listing	27.5	30.7	.74	.85
Harrowing	9.2	10.1	.22	.24
Go-deviling	19.7	23.1	.39	.59
Cultivating (second)	26.1	29.4	.57	.69
Cultivating (third)	23.6	26.0	.54	.56
Total	126.4	139.1	2.93	3.45

While the difference was not great in the time and fuel used per acre by tractor operators for any indi-

[1] Junior clerk, economic research division, Northern Great Plains Region, Soil Conservation Service, Lincoln, Nebr. Credit is given to Earl L. Struwe, assistant agricultural economist, division of economic research, Soil Conservation Service, for assuming responsibility in collecting the data; and to L. F. Garey, professor of rural economics, College of Agriculture, University of Nebraska, for many helpful suggestions concerning the study.

[2] Plum-Beaver soil conservation district in Boone and Nance Counties, Nebr.

[3] Summary of Results of the Nebraska Tractor Tests. Bulletins Nos. 265 (Jan. 1932), 304 (Jan. 1937), and 321 (Jan. 1939). Agricultural Experiment Station, College of Agriculture, Lincoln, Nebr.

vidual operation on contoured and noncontoured fields, the cumulative difference for all operations, as shown by the data in the table, indicates a saving for those farmers who followed contouring. This saving amounted to approximately 14 minutes of time and one-half gallon of tractor fuel per acre. Since the average field was approximately 30 acres in size, this would indicate a total saving of 7 hours of time, and about 15 gallons of tractor fuel for all the operations involved in seedbed preparation, planting, and cultivating each field farmed on the contour. By farming on the contour the average operator saves enough time per acre to cover an additional one-tenth of an acre or, on a field basis, an additional 3 acres. His fuel saving would permit him to cover even a larger area.

Table 2 indicates the average time used for the several operations performed by the farmers who used horses as a source of power in producing listed corn.

Table 2.—Average time used per acre on 23 contour- and 14 noncontour-listed corn fields

Operation	Man time per acre		Horse work per acre	
	Contoured fields	Noncontoured fields	Contoured fields	Noncontoured fields
	Minutes	*Minutes*	*Minutes*	*Minutes*
Disking	37.2	43.9	168.1	198.2
Listing	80.3	79.1	321.2	316.4
Harrowing	20.0	17.4	80.0	69.6
Go-deviling	40.7	38.8	162.8	155.2
Cultivating (second)	64.7	63.3	165.6	162.0
Cultivating (third)	51.4	71.8	199.0	192.0
Total	294.3	314.3	1,056.7	1,093.4

As in the case of the tractor farmers, a saving of time was observed for the operators who used horses as a source of power in farming on the contour. The saving amounted to approximately 20 minutes of man labor and 36 minutes of horse work per acre for the operators who contour-farmed, as compared with those who did not. Since the average field of corn, farmed by operators who used horses as a source of power, was approximately 23 acres, the total saving effected per field amounted to about 7 hours and 40 minutes of man labor and 13 hours and 48 minutes of horse work.

Another fact of interest is the more efficient use of man labor on the tractor-farmed fields. The same operations consumed approximately twice as much man labor when horses were used as a source of power as when tractors were used.

Barley and oats were seeded by drilling with a grain drill and by broadcasting with an endgate seeder on both contour- and noncontour-farmed fields. The usual tillage practice followed when the grain was seeded with a drill was a double disking immediately preceding the drilling operation. When the grain was seeded broadcast with an endgate seeder, the more common practice was to scatter the seed and follow up with a single disking and a harrowing operation. The difference between contoured and noncontoured fields that were seeded by the broadcast method was that all operations were performed on the contour on the former fields.

Tables 3 and 4 indicate the average time and fuel used for each operation on fields farmed by both methods. Table 3 is based on the performance of the tractor and tractor-equipment operations, while table 4 shows corresponding results where horses were used by the farmer.

Table 3.—Average time and fuel used per acre in seedbed preparation and seeding of small grain on 11 contour- and 7 noncontour-drilled fields

Operation	Man labor per acre		Tractor fuel per acre	
	Contoured fields	Noncontoured fields	Contoured fields	Noncontoured fields
	Minutes	*Minutes*	*Gallons*	*Gallons*
Disking	20.3	19.8	0.47	0.52
Do	20.3	19.8	.47	.52
Drilling	23.0	29.5	.55	.61
Total	64.5	69.1	1.49	1.65

Table 4.—Average time used per acre in seedbed preparation and seeding of small grain, using horses on 3 contour- and 2 noncontour-drilled fields

Operation	Man labor per acre		Horse work per acre	
	Contoured	Noncontoured	Contoured	Noncontoured
	Minutes	*Minutes*	*Minutes*	*Minutes*
Disking	37.2	43.9	168.1	198.2
Do	37.2	43.9	168.1	198.2
Drilling	55.0	56.5	219.8	226.6
Total	129.4	144.3	556.0	623.0

These tables reveal that the operators who seeded their small grain on the contour used slightly less man labor, horse work, and tractor fuel than those who farmed up and down the hill. The use of horses, apparently, is not as popular as the use of tractors as a source of power for drilling small grain in the Plum-Beaver district.

Tables 5 and 6 show the average time and fuel used by the farmers who used endgate seeders for broadcasting the small grain seed.

Very little difference was found in the time and fuel used by the two groups of operators who seeded small

Table 5.—Average time and fuel used per acre in seeding small grain by broadcast method, using tractors and horses on 9 contour- and 5 noncontour-farmed fields

Operations	Man labor per acre		Horse work per acre		Fuel used per acre	
	Contoured	Noncontoured	Contoured	Noncontoured	Contoured	Noncontoured
	Minutes	*Minutes*	*Minutes*	*Minutes*	*Gallons*	*Gallons*
Broadcasting	13.8	13.2	27.6	26.4	....	....
Disking	20.3	19.8	....	....	0.47	0.52
Harrowing	9.2	10.1	....	....	.22	.24
Total	43.3	43.1	27.6	26.4	.69	.76

Table 6.—Average time used per acre in seeding small grain by the broadcast method, using horses as the source of power on 13 contour- and 11 noncontour-farmed fields

Operations	Man labor per acre		Horse work per acre	
	Contoured	Noncontoured	Contoured	Noncontoured
	Minutes	*Minutes*	*Minutes*	*Minutes*
Broadcasting	13.8	13.2	27.6	26.4
Disking	37.2	43.9	168.1	198.2
Harrowing	20.0	17.4	80.0	69.6
Total	71.0	74.5	275.7	294.2

grain by broadcasting with an endgate seeder and followed up with a disking and a harrowing operation.

Although some variation was evident in the efficiency of performance among the individual operators, the data presented in the preceding tables indicate that less time and power were used for contour operations than for up-and-down-hill operations in the Plum-Beaver soil conservation district. The relative amounts of these savings may be ascertained by comparing the height of the bars in the accompanying chart. The performance on the up-and-down-hill farmed fields is represented as the standard, or 100 percent.

While the economies effected on contour-farmed fields in man labor, horse work, tractor and equipment use, and tractor fuel are not very large for the individual operator, they are of sufficient importance to merit the consideration of every farmer who is interested in increasing his efficiency and economy of operation. The implications of this reduction in time and power requirement are that farmers who adopt contouring as a part of their farming system are in a better position to (1) improve their timeliness of operations having seasonality, (2) increase their productivity, and (3) reduce their costs of production. However, due to severe drought conditions in this district during the 1939 crop season, evidence is lacking of the advantages gained from increased productivity due to timeliness of operation. Data obtained in this district in other years do indicate that crop yields were slightly higher on farms where the recommended practices were followed, and that the yields decreased with an increase in erosion. Since the cost of production up to harvest for the crops studied is not affected by the yield, it is safe to conclude the existence of an economic advantage in contour farming, even with the same yield, because of the saving in both labor and power when compared with up-and-down-hill farming. Any increase in yield resulting from contour farming would add still more to its economic advantage.

STRIP CROPPING

(Continued from p. 38)

deep on the highway at the lower edge of the field. It was impossible to estimate the amount of soil that was washed down the creek. Incidentally, the two tracts had been operated as one farm until 1937; hence, previous management methods would not account for the difference.

From a demonstrational standpoint, that one rainstorm did more good than a hundred speeches. The men at the Carlisle camp suddenly found themselves unable to cope with the flow of requests that came in for assistance in laying out strips. The energetic county agent did what he could, but he too fell behind in his work.

Thus Bourbon County farmers initiated their own soil-conservation program. Several of them began contour farming and strip cropping before agreements were signed. One noncooperator bought a field level like the one used by the camp and laid out contour strips on his five farms. Farmers in nearby Mason County, seeing the spread of strip cropping, hired their own engineers. Meanwhile, with every cropping season and every rain, the land of burley and the land of thoroughbreds is rapidly becoming the land of contour strip cropping.

HOPI WATER CONSERVATION

(Continued from p. 48)

Simple brush windbreaks have proved an important aid to the protection of crops of beans, melons and squash. The measures now employed in the Hopi country are suggestive of methods which probably prevailed among the Pueblo villages in the primitive agriculture of the Southwest.

(Editor's Note.—Literature citations were omitted for lack of space. Inquiries regarding source material should be directed to Dr. Stewart.)

BOOK REVIEWS AND ABSTRACTS

by Phoebe O'Neall Faris

LAND ECONOMICS. By Richard T. Ely and George S. Wahrwein. New York, 1940.

This book is not in any sense "light reading," but it can and should be read for background by all of us who want to appreciate the actual objectives of the work of our Service. Many times we reach the point of wondering whether or not it is humanly possible to coordinate land policies and population trends for the safety of the land and the good of the race. If such coordination is to be attempted, then what are the factors that must be viewed from all angles in framing land policies for the good of the people? Some of us may go a little further in our thinking: If the land is for the people, then what are the people for? The new volume reviewed here should help greatly in thought processes which we hope will lead to solution of some of the problems regarding occupation and use of the world's land by two billion people.

In the first 20 pages some striking population trends and figures are introduced, and no doubt it was the authors' intention to show in the beginning that regulation of population numbers is not to be expected. Be that as it may, the book swings quickly over to the physical factors of land occupation and utilization. Climate as related to man is the first factor discussed; topography, soils, water in all its phases, land quality gradations, minerals and forests, and even subsurface and supersurface resources—all these are drawn together as land, or nature, in the attempt to give a clear picture of the economic problems of land use and productiveness at the hand of man.

Two chapters, "Land as Space" and "Land as Property" are quite new in compilation if not in concept. Room and situation, according to the authors' opinion, are land's only original and indestructible powers. They have gone far afield in gathering thought, idea, and opinion on the productiveness of land when labor and capital are applied to it, and in discussing means of determining the point where the "static law of diminishing returns" sets in. Their discussion of the expansibility of economic space gives rise to much thought and conjecture as to modern restlessness and the fate of the land, call it "space" or call it "property." In the chapter on property, the human attribute, ownership, is discussed from the standpoint of its influence on land utilization and land value. Here the writing is scholarly, unusually swift in thought continuity, and world-wide in scope, even though most of the concrete material is "United States." The idea of property is somehow unpleasant to think about, since except within his own mind man can never hope to own the world; yet there is no doubt that the many-faceted story of man's everlasting struggle for some part of the planet, down to the center of the sphere and up to the heavens, has become throughout the past 10 thousand years part and parcel and sometimes all of human existence. Those who think beyond economics may wonder which has, and may, suffer the more from man-made property "rights" extending even to the air—Earth or *Homo sapiens*. But property, ownership, possession, is another matter entirely when it comes to agriculture—making use, good or bad, of the land of the world for the good, or harm, of the human race.

In the discussion of "property" the authors of this book set up their thesis by showing how, throughout the world, private property in land became valid, step by step, after "agriculture superseded grazing" until in the present era utilization of land by man demands a fine proportioning of social, commercial, and physical factors if land resources are to be used and at the same time conserved in a state of production for the future. Many extremely interesting and important trends and developments of past centuries are described: the "Dorf" or agricultural village as the unit of the feudal system; seigniorial tenure of Quebec resulting in "ribbon farms" impossible as economic units; alienation of public lands in the United States and Canada; Indian lands in the New World and a people who "had little or no concept of private property and were not aware of the rights they were surrendering." Social and political privileges associated with landed property during past centuries and in the present era, as discussed in this book, give rise to serious consideration of the dependence of state and federal governments upon "private property in land" in building land-utilization plans and programs.

In Chapter 5 the authors get down to the economics of land utilization in a world most of which "lives under a regime of private property in land." Production and land values are treated by the method of proportioning the many factors involved in making use of land and by applying the law of diminishing returns to determine increments from inputs. Rent, value of land, size of unit, management, institutional elements, competition, and costs of utilization are treated with much attention to detail and what might be called "subfactors." By proportioning all the factors the authors set the stage for their main theme—that "agricultural land can go longer without being repaired or replaced than other forms of agricultural capital" but that "inasmuch as farm land is subject to deterioration, the income of the operator must be sufficient to cover the cost of maintaining the productivity of the land." After this, the book becomes definitely a treatise on utilization of land for conservation of soils and all other natural land resources.

Agricultural land, as of prime importance in a world where human beings must live and produce food to live, is discussed first from the point of view of types of farm organization. In view of the two decades just past and the agricultural problems arising out of intensive industrialization of many areas of the United States, the authors' views on self-sufficing and peasant agriculture, and farming as an industry, are most illuminating in that they point out clearly wherein lie many of the most serious difficulties in soil-conservation and land-reclamation programs as related to future land-utilization policies. An excellent analysis of future demands and trends is to be found in the latter half of the chapter "Agricultural Land"; it is especially recommended for soil-conservation planners.

A specialized treatment of agricultural land tenure as related to soil conservation in the United States is presented in Chapter 7, and here is found considerable information regarding the work of the Soil Conservation Service. The soil conservation district is referred to as "the real impetus * * * to erosion control by collective action" in the United States. "Undoubtedly," state the authors, "these districts will, and in fact should, operate for some time before enacting land-use regulations, to permit ample time to gain experience with voluntary action."

U. S. GOVERNMENT PRINTING OFFICE: 1940

Erosion-control operations by government foresters on formerly cultivated land, after the land has been ruined by erosion, near Tzintzuntzan, Mexico.

TZINTZUNTZAN TO SINGAPORE

By H. H. BENNETT

Chief, Soil Conservation Service

AT TZINTZUNTZAN, archaeologists had been digging into the remains of the "city of kings" of the Tarascan Indians. I had to take the word of the diggers as to what was being found beneath the surface of the ground—what relics of this old, old race of agricultural Indians were being brought to light. But there was no difficulty in seeing what had taken place at the surface of the earth. Across the succession of centuries the Tarascans had used the lands out there on the southwestern edge of the great Mexican plateau, some 200 miles west of the City of Mexico.

The land scars to be seen in that locality are enough to jolt the most experienced student of land conditions. Here at Tzintzuntzan and all around the basin encircling Lake Patzcuaro, and far back into the mountains to the east, erosion has taken heavy toll of the land. The damage is measurable in terms of hundreds of thousands of acres. A very large portion of these thousands of damaged acres—probably several million acres—has been so gullied or severely washed that the land is no longer useful for cultivated crops. Gullies—thousands of them—extend from the foot to the crest of many high hills; with other thousands reaching part way up, in a maze of trenches that have cut away the soil to depths of 10, 20, or 50 feet, or more—often, down to bedrock.

From a hilltop near the west side of Lake Patzcuaro, my companion and I estimated the area of erosion-destroyed land visible immediately around us at 12,000 acres. In a few places, tongues or island strips of soil—rather, of subsoil—are all that remain. In other places, pedestals, 4 to 10 feet high, showed that the bare, exposed rock all around once was covered by soil which had a subsoil depth at least as thick as the height of the pedestals.

At the present time, the Tarascans out of necessity—because of scarcity of productive land—are

Twenty-five years ago this Ottawa County tract was in farmland.

clearing mountain slopes so steep that severe erosion begins with the first year of cultivation.

Although they are an ancient race of agricultural people, strongly attached to the ways of tradition, they apparently have never looked upon the soil as a destructible resource. If they ever have realized that their productive land probably is the only thing that can save them from extinction, they have not changed their methods from the wedded ways of tradition; and they have done nothing to conserve the soil. They sometimes plant corn with a wooden stick, such as was used, according to the excavations of archaeologists, many centuries ago.

I do not think the Tarascans realize yet that they are coming very close to the limits of agriculture in the area that has been Tarascan for so many centuries. The yields of wheat seldom run above 3, 4, or 5 bushels per acre in most of the fields one sees in traveling about the country—although wheat is one of the principal crops. Erosion has affected directly both upland and footslopes; indirectly, the process has affected lowlands by deposition of poor subsoil material washed down from gullied hillsides.

After seeing all this land impoverishment and wreckage in the southwestern Mexican highlands, one is rather rudely jerked up on seeing the excellent results in soil conservation obtained with simple measures used by other groups of Indians in other parts of the highlands of Mexico, as in the hills south of the City of Mexico. Here, one finds benches of deep soil accumulated behind substantial stone walls that were built across the slope, I was told, long before Cortez captured Mexico. In many parts of the State of Michiocan— the center of the Tarascan civilization—gullies extend up and up the slopes in striated patterns of land destruction and agricultural exhaustion. In contrast, the country south of the City of Mexico reveals rock-supported terraces that ascend far up many slopes in bench-like patterns of conserved soil capable of supporting a continuous and rewarding agriculture.

I must confess that I can offer no explanation as to why the agricultural Indians in one part of Mexico have so completely left out of their culture all conception of the need for land protection, while the Indians in some other parts of the country, occupying much the same type of terrain, included in their culture a very fine conception of the need for preserving their most basic natural resource. This question was just as baffling to me as was the purpose behind the performance of the Ancients of Mexico who built such magnificent structures as the Pyramid to the Sun, at Teotihuacan.

Later, July 1940, at Singapore, 2,000 miles to the north, I was almost as much amazed as at Tzintzuntzan when I encountered a chimneytop after taking out a few spadefuls of sand on the crest of the sand dune at Saugatuck, on the west coast of the lower peninsula of Michigan. On the way to Singapore, which is, or was, about 70 miles north of the southwestern corner of the State, we were seldom out of sight of the effects of water erosion, or wind erosion, or both. In some vineyards, where the rows ran straight down the hill, we had picked up dead grapevines whose entire root system had been exposed by erosion—an effect representing the removal of more than a foot of soil and subsoil by continuous washing of the unprotected slopes. Not finding Singapore on the map, I was informed by my traveling companions that a satisfactory system for showing the location of towns like Singapore and Dewey, Mich., had not been worked out for the variety of highway maps we were using. The

trouble with putting Singapore on the map is due to the fact that the whole town has been blanketed over by a sand dune that moved eastward from the direction of Lake Michigan. The place once had a reputation as a lumber port of importance around the 1840's. But the removal of the forest from the sandy lands of the locality set in motion a scourge of wind erosion that eventually annihilated this lumber town on Saugatuck Bay.

Continuing north to Holland, carrying along a number of bricks and other remains exhumed at Singapore, we met two of the supervisors of the West Ottawa Soil Conservation District and promptly started out on a tour of the wind-eroded section of the district. I was told by the supervisors that 30,000 acres of land in that one district were bare and on the move as the result of wind erosion. It seems that in this part of Michigan, as well as many other parts, more sandy land has a tendency to blow rather violently after a few years of cultivation or overgrazing. The supervisors said that considerable land was affected by water erosion in the more rolling parts of the district, but they urged that we devote our time particularly to the wind-eroded section because of the wide distribution of the affected areas and the immediate necessity for getting them under control. They even spoke of the overwhelming magnitude of the job of soil conservation immediately out in front of them. When I asked if they meant that they were approaching the point of giving up, they came back instantly with the assurance that they not only were not anywhere near the point of surrendering but very definitely felt that the work already accomplished was proof that erosion could and would be whipped through the use of practical control measures. "This district," one of the supervisors said, "began operations in the spring of 1939, but our farmers already have planted 700,000 trees and a great deal of beach grass, chiefly for controlling wind erosion in the sandy plains section."

They took me to the district nursery, where another million trees will be ready for planting very soon, and where an additional area is being prepared for enlarging the nursery. I think everyone who sees the erosion-control accomplishments of the C. C. C. camp working under the direction of the Soil Conservation Service, now aiding the district, is proud of what these boys are doing. In addition to what the farmers have planted, the C. C. C. boys have set out 900,000 trees, largely for stabilizing blow land.

We went over a completely successful sandy land stabilization job, where raw dune sand was creeping across farm land and roads in a very destructive manner. So loose and shifty was the blow sand,

Paling to halt drifting sand in the West Ottawa soil conservation district, constructed by C. C. C. enrollees. Small trees were planted in the spring of 1940 to establish permanent protection.

Even a thin mulch of wheat straw (about two tons per acre) is effective in protecting this Michigan orchard from erosion.

it seems entirely impractical for any easy control operations to be imposed; but precisely such operations had been carried out with perfect success by the erosion technicians and C. C. C. labor. Pine seedlings had been set out within squares planted to beach grass. The nine trees per square stood like brave little sentinels distributed over a compound. It was really amazing how such diminutive plants had in the course of a few months pretty effectively quelled the wrath of the wind which had been driving ahead loose sand having little more stability than the wind itself.

I left the supervisors of the West Ottawa Soil Conservation District with the feeling that not only would the 30,000 acres affected by wind erosion be put speedily under control, but that many other thousands of acres on the point of drifting, as well as the areas subject to water erosion, would be safeguarded.

Thus bolstered, I was able to withstand another shock at Grand Haven. Here, as we drove into the city, one of the erosion specialists opened a book dealing with the history of Ottawa County, which showed a picture of Dewey, across the river from Grand Haven, as it looked in 1886. It was a good picture, and Dewey was a clean-cut, prosperous-looking town. But when they took me to the river's edge and pointed across to a towering sand dune, saying "you are now looking at what once was the city of Dewey," my thoughts again ran back to Tzintzuntzan, where archaeologists had to dig through the products of erosion in order to get at the handiwork of the ancient Tarascans.

I was told that it costs around $28,000 annually to remove the sediment, largely wind-driven sand from the dune that had blotted out Dewey, from the harbor at Grand Haven in order to maintain adequate depths for navigation. I was told also that the sand was carried out into the lake on scows and dumped. Perhaps that is the only practicable way the dredged material can be disposed of, but it is somewhat discomforting to think that so much must be expended to remove eroded soil material in this circular sort of way, which will permit the material eventually to come back to the same place it was picked up.

Recalling that someone had spoken of dredging operations at Benton Harbor and Saugatuck, I asked for a rough estimate of the annual cost of keeping the harbors around the entire coast of Michigan adequately dredged. The reply was that it probably is $100,000 at least for such operations—or more than was being spent by the Government in cooperation with the five soil conservation districts which had been established in the State at the time. (On the same day we went over the West Ottawa District, another soil conservation district—the sixth in the State—which was voted for an area in another part of Ottawa County.) From Grand Haven and the sandhill that had obliterated the town of Dewey from the face of the earth, we drove northward to Traverse City to

Sodded diversion terrace outlet established by the S. C. S. demonstration project in an old established orchard, Grand Traverse County, Mich.

inspect soil conservation work in that vicinity. On the way, we again were seldom out of sight of the effects of erosion, except while passing through occasional patches of wooded country. By the time Traverse City was reached, I was ready to ask, "How much erosion do you have in Michigan, anyway? I hadn't supposed there was anything like the area we saw today and yesterday."

I had heard a good deal about the cut-over sandy lands of the State, of rich muck soil and Kalamazoo celery, of Traverse cherries and prosperous farms, but certainly had not expected to see so much soil erosion. The answer to my question was: "Five million acres of land, mostly farm land, seriously affected by erosion, and approximately 600,000 acres of this pretty much ruined for any immediate practical crop use."

I should have pointed out that we were visiting the Grand Traverse County section not only to study erosion control and water conservation work but to attend and speak at the National Cherry Festival.

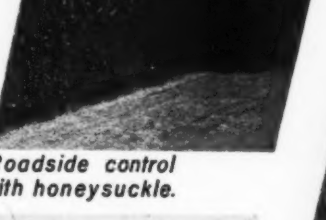
On the following day, we spent the forenoon and afternoon examining soil conservation work on farms cooperating in the demonstration projects centering about Traverse City. Farms were visited both along the mainland bordering the east arm of Grand Traverse Bay and on the Old Mission Peninsula that projects so beautifully into the bay. On the tour there were leading farmers, county agents, erosion technicians, and representatives of various State and Federal agricultural agencies. We saw cherry, peach, and apple trees planted on the contour, and alternate inter-row cultivation with inter-row protective cover, usually a legume or grass. We saw hay- and straw-mulching, grassed waterways, contour strip cropping, field strip cropping, contour rotations, tree plantings, and other measures applied to fit the needs and adaptabilities of the various kinds of land.

Of special interest to me was a large farm where potatoes were grown in rotation with corn (or radishes), oats, and alfalfa. Here in a field, contour strip cropping was effectively controlling erosion. We were informed that previous to the installation of this conservation practice in 1940, erosion sometimes would cut deep washes across the entire moderately sloping area, some of which were difficult to cross with farm machinery. We were told also that 30 years of farm records showed that this eroding field had produced an average of about 30 bushels of wheat for the years it was used for wheat, as against an average of 45 bushels of wheat on a less sloping, adjacent tract of the same original type of soil, which had not suffered very much from erosion. The yields of wheat in the two fields were practically the same in the beginning, but recently

(*Continued on p. 67*)

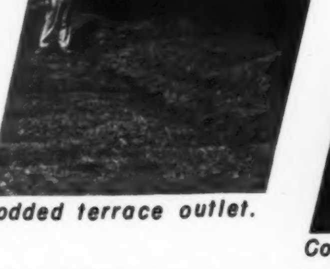
BUILDING WITH LIVE MATERIAL

Earth dams may be protected from erosion by vegetation.



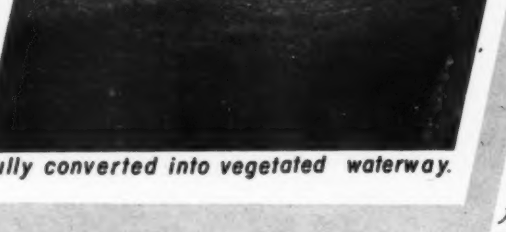
Roadside control with honeysuckle.

Streambank protection with willows.



Sodded terrace outlet.

Constructed spillway protected by vegetation.



Gully converted into vegetated waterway.